THE OCCURRENCE
OF
COBALT and VANADIUM
in
Mt REMUS PYRITIC ORE

Cobalt & Vanadium in Mt
Remus Pyritic Ore.
by
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THE OCCURRENCE OF COBALT AND VANADIUM IN MT. REMUS PYRITIC ORE.

Small samples (Nos.1017, 1018) of pyritic ore from lease 1009/M, applied for by the Mt. Remus Prospecting Syndicate at Mt. Remus, Tasmania, have been submitted for examination by Mr. P. B. Nye, Government Geologist of Tasmania, by whom the ore occurrences of the area have been described in a report on the Molybdenite Prospect at Mt. Remus, dated December 14,1928. The amounts of molybdenum, cobalt and vanadium contained in the pyritic ore are indicated by the following determinations:-

	No.1017	No.1018
M_oS_2	0.47	0.48
C_o	0.54	0.49
V	0.35	1.49

The composition of the ore is shown by the following analysis of a bulk sample (1019).

Mo	0.48
Co	0.498
V	1.57
Fe	39.08
S	49.70
Insol.	8.88
	100.208

In addition it has been determined that lead and copper are absent and that nothing more than traces of arsenic, nickel and zinc occur.

The ore thus consists mainly of pyrite with small amounts of molybdenite, and, being very friable and crumbly in character, the preparation of sections for microscopic examination provides more than ordinary difficulties.

Examination of Polished Sections.

The microscopical examination of polished sections in reflected light reveals, apart from transparent minerals, pyrite molybdenite and a small amount of hematite. The friable character of the ore is found to be due to the separation of pyrite particles by thin divisions and masses of chlorite.

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The pyrite is fairly coarse grained and no mineral is revealed by differences in colour and polishing which can be ascribed to a cobalt mineral.

In the absence of Ni and As, the only possible cobalt mineral is cobalt-pyrites or linnaeite, CoS_2. Linnaeite is similar in colour and behaviour to pyrite, except that it is tarnished by $HgCl_2$ while pyrite is not.

The section was therefore etched with $HgCl_2$ and the pyritic mass found to be composite. Roughly half the pyritic crystals are not tarnished by $HgCl_2$ and therefore pure pyrite, and the remainder are tarnished. A tarnished particle was then excavated and tested microchemically. After dissolving in HNO_3 the solution contained a great excess of iron, while the potassium nitrite test for cobalt gave a positive result. The mineral is therefore a cobalt bearing pyrite. The varying porportions of pyrite and cobalt bearing pyrite is one factor in producing a variable percentage of cobalt.

Molybdenite occurs sporadically in small segregations composed of small granular crystals, some of which appear broken and in which the prominent cleavage is recognisable. It possesses characteristic bireflection (reflection-pleochroism) and shows strong anisotropic effects between crossed nicols. Corroded crystals of pyrite occasionally occur embedded in molybdenite and suggest that the development of molybdenite is later than that of pyrite. In addition, molybdenite areas contain patches of transparent chlorite, while along some cleavage planes and surrounding crystal grains are very thin dark lines representing a mineral whose identity is uncertain though it may be molybdic ochre.

Small isolated irregular grains of hematite and possibly magnetite occur isolated in the areas of soft transparent chlorite. They are grey in reflected light and occasionally show a trace of reddish internal reflections indicating hematite.

Examination of Thin Sections.

The examination of thin sections in transmitted light determines the character of the gangue minerals which appear dark in

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the polished sections in reflected light. These minerals are found to be essentially chlorite, epidote associated with a little zoisite, and occasional particles of quartz and a colourless mica.

Green chlorite is the most abundant and forms scaly aggregates which extend as thin wrappings around pyrite crystals and account for the friable character of the ore. In addition to the fine scaly masses, distinct, pleochroic flakes of chlorite occur and some of the flakes are grouped radically. In one section, some of the chlorite shows a brownish colouration, suggesting at first its derivation from brown biotite. This however is doubtful as none of the brownish areas possess polarization colours like biotite and they may have resulted from the oxidation of the iron in the chlorite during the heating in the cementing processes prior to the preparation of the slide.

Associated with the chloritic masses are scattered opaque grains of hematite or magnetite and also occasional particles of quartz and a colourless brightly polarising mica. Such mica may be the vanadium mica, roscoelite, but as it only appears as an isolated grain in one section it is insufficient to account for the general percentage of vanadium.

Epidote with subordinate zoisite is associated with the chloritic masses and in part forms clusters of crystals in the pyrite almost to the exclusion of chlorite. The identification of epidote is hampered because, though the sections are thick, there is an absence of pleochroism and in many grains showing cleavage traces there is apparent straight extinction. Some grains however show oblique extinction. The refractive index is in the neighbourhood of 1.7 and the double refraction is moderately high and third order polarization colours appear even in the thinnest parts of the sections. The form of the grains, cleavage refractive index and double refraction coincide with those of an epidote, rather poor in iron and the identification is supported by its association with zoisite, which is more readily identified.

In some cases rectangular prisms of zoisite are found embedded in chlorite on the margins of epidote clusters. These are clearly recognisable by the high refraction, very low double refraction, straight extinction and biaxial character. Other grains occur among the epidote crystals, some of which are normal to an optic axis. These show a biaxial interference figure in which the optic axial angle is very small and from which the optical character is determined to be positive. Iron stained grains sometimes occur in the chlorite which may represent oxidised residuals of epidote.

Discussion.

The problem of the ore is the determination of the host minerals of cobalt and vanadium. The absence of a cobalt mineral species is negative evidence of its presence in the composition of pyrite. Cobart bearing pyrite is known, though rare, (W. Vernadsky Cent. Blatt, Min. p.494, 1914) and it is usually accompanied by nickel which has been proved to be absent in this case. This conclusion however has to be reconciled with the following reported analysis of selected molybdenite from the occurrence.

Mo	45.67
V	4.38
Co	0.63
S	38.24
Fe	8.20
	97.12

This analysis indicates, as pointed out by Mr. Nye, a sample containing approximately 76% molybdenite and 17% pyrite. The percentage of pyrite is greater in the average ore where the percentage of cobalt (0.498) is less than in this sample of selected molybdenite (0.63). It must therefore be assumed that the pyrite associated with the molybdenite is essentially all cobalt bearing while approximately half of it in the average ore is pure pyrite.

Vanadium is in all probability, contained in the composition of the chlorite. Vanadium bearing micas are well known and while, as previously stated, there appears to be insufficient vanadium bearing muscovite, vanadium bearing biotites are also known. Chlorite derived from such may therefore be vanadium bearing.

The possible existence of patronite VS_4 has been investigated chemically by Mr. Bath, Government Chemist and Assayer. It appeared from the bulk analysis that there was an excess of sulphur in the bulk analysis after alloting sulphur to the pyrite molybdenum and cobalt.

Iron	39.08	equiv. sulphur in FeS_2	44.73
Mo	0.48	equiv. sulphur in MoS_2	0.31
Co	0.498	" " " CoS_2	0.57

As the total sulphur in the bulk analysis is 49.70 there is a surplus of 4.04% which corresponds almost exactly to VS_4.

Analyses were therefore carried out by Mr. Bath in accordance with the procedure outlined by W. F. Hillebrand in a paper on Patronite (Amer.Journ.Sci.Vol.XXIV, 1907 p.141). This involved

1. Removal of free sulphur by repeated treatment with carbon disulphide, and determination of same.
2. Thorough drying of material and apparatus.
3. Extraction of residue from (1) and (2) with hot water and determination of vanadium and sulphate in extract.
4. Extraction of residue from (3) with warm caustic soda until filtrate came through uncoloured. Determination of Vanadium and sulphide in extract.
5. Treatment of residue from (4) with conc. nitric acid and determination of cobalt in extract.
6. Determination of carbon in residue from (5)

The results from these operations on sample 1019 were

(1) Free sulphur (approx.) 0.03% of original sample

(2) Hot water extraction

Vanadium	nil
Sulphate (SO_4)	1.08%

(3) Caustic soda extraction

Vanadium	0.042%
Sulphide sulphur	0.043%

(4) Nitric Acid solution

Cobalt	0.47%

(5) Residue

Carbon (approx.) 0.45% unable to determine sulphur in this owing to it having been acid treated.

These results indicate that only a very small proportion of the vanadium (0.042% compared with 1.57%) is soluble in caustic soda. The small amounts of vanadium and sulphide which did dissolve in caustic soda correspond to a vanadium sulphide of the formula V_2S_3. It is clear therefore that vanadium sulphide is not the source of the vanadium in the ore and such traces as appear to be present do not correspond to patronite whose composition is VS_4 or perhaps V_2S_5. Further it appears that the traces of sulphide in the caustic soda extract may be due to the solubility of molybdenite in caustic soda. ~~It may be due to the solubility of molybdenite in caustic soda.~~ It has also been observed that there is a slight attack on the chlorite by caustic soda and therefore the vanadium may have been derived from chlorite.

The high percentage of vanadium (4.38%) in above analysis of the selected molybdenite seems to be at variance with the view that vanadium is contained in the chlorite. While it is likely that some chlorite has been entangled in the analysed sample of molybdenite, the summation of the analysis indicates that only an insufficient percentage of chlorite could be present in the sample.

It appears therefore that the high percentage of vanadium in the analysis of selected molybdenite is due to some fortuituous circumstance, such as a slight contamination with an oxidised compound containing vanadium. This view seems to be substantiated by the following analyses of the Mt. Remus ore.

MoS_2	5.12	1.14	0.64	31.2
V	0.89	nil	0.92	tr
Co	1.22	0.85	nil	0.3

These analyses show there is no relation between vanadium and molybdenum and the last example containing 31.2% MoS_2 and only a trace of vanadium is a result which would be expected from the microscopic examination of the segregations of molybdenite in the examined specimens.

(Sgd.) Frank L. Stillwell,

October 5th, 1932.